Why the Hardness Test Can Not Determine Yield Strength

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• A hardness value might be correlated to the ultimate tensile strength (UTS or TS) because it is measured at a high strain value of 8-10% (depending on the indenter geometry) where the stress is near the necking point or UTS.

• However, a hardness value cannot be correlated to the Yield Strength (YS) at a small strain value (0.2% offset or 0.5% for pipelines) because pipeline steels have various shapes of their stress-strain curves and there is no correlation between UTS and YS.

• The 1999 Battelle/ASME report accurately demonstrates these facts with the hardness, YS and TS values from numerous pipeline steels. This report was not accepted by PHMSA for pipe grade or YS determination.
Data from Battelle’s report demonstrate that there is no reliable correlation between Yield Strength and Hardness Values. There is no physical basis for correlating a hardness value near UTS (at a high strain of 8-10%) to a yield strength at a low strain value (0.2 or 0.5%) while the shape of the stress-strain curve varies with the pipeline grade and thermo-mechanical condition.
Data from Battelle’s report demonstrate that there is no reliable correlation between Yield Strength and Ultimate Strength. Again, there is no basis for any correlation to exist because all steel materials do not have one shape for their stress-strain curves. Pipeline grades have different ductility values and work-hardening behaviors.

The Regulation for determining pipe grade requires three items: minimum yield strength (YS), minimum ultimate tensile strength (TS), and maximum ratio of the YS/TS.

If pipeline steels had one shape of stress-strain curve, there would be no need for the ratio of YS/TS.
In 2009, the same authors used the Report as a basis for a research report, *CRTD-Vol 91, Applications Guide for Determining the Yield Strength of In-Service Pipe by Hardness Evaluation*.

On page 2 the authors state that the Battelle 1999 project “established a statistically based relationship between yield and hardness of steel pipe” where the actual report shows a trend, not a reliable relationship, and the trend between hardness and yield strength can vary by 100%.

The shot-gun results of the 1999 report are not included in the “Guide.”

The “Guide” misleads the pipeline industry by appearing to give the ASME “stamp of approval” to faulty research.

The ASME CRTD-Vol. 91 Final Report is a research report not a standard or a code. It must not be used or referenced as a standard.
Further Misleading Information in the “Guide”

• Continuing the faulty premise that hardness will provide reliable yield strength, the authors provide a review of numerous commercially available hardness testers.

• However, the authors conflate the technology owned by Fahmy Haggag and ABI Services, LLC, known as Automated Ball Indentation (ABI), with a category of hardness testers known as Instrumented Indentation Testing (IIT). The IIT equipment is provided by the Korean company Frontics.

• At no point, do the authors refer to any of Haggag’s work or equipment when using the terms “Automated Ball Indentation” or “ABI.”

• ABI®, an indentation technique, is a mechanical test with similarities to a tensile or compression test. It uses different hardware and processes than the IIT test. It is not a hardness test and does not use correlations to estimate yield strength.

• ASME refused to make any corrections to the erroneous conflation of IIT to ABI® and chose to use its status as a Standards Development Organization (SDO) to avoid accountability.

The research to use inline hardness testing to estimate the yield strength and then establish the Maximum Allowable Operating Pressure (MAOP) is presented as reputable and reliable based on the ASME Guide. “…. Governed by *ASME, CRTD 91, Applications Guide*..., which specifies accuracy standards and a process for using these testers in the field.”

The article discusses the accuracy of their portable hardness tester as compared to the laboratory equipment and how the processes are consistent with the ASME Guide, but it does not discuss the fact that hardness is not related to yield strength. The 49CFR Parts 192 and 195 Regulations neither specify nor require any hardness measurement. Also, one cannot estimate three values of YS, UTS, and YS/UTS from a single hardness point.

Will ASME accept accountability when pipelines fail and lives are lost based on faulty hardness estimates it endorses?